International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN (P): 2249-6890; ISSN (E): 2249-8001
Vol. 9, Issue 4, Aug 2019, 1-10

A METHOD FOR REDUCING THE TOOTH PROFILE ERRORS OF THE SPUR GEARS IN THE HOBBING PROCESS

MINH TUAN NGO[1] & VINH SINH HOANG[2]

[1]*Faculty, Department of Mechanical Engineering, Thai Nguyen University of Technology, Thai Nguyen City, Vietnam*

[2]*School of Mechanical Engineering, Hanoi University of Science and Technology, Hanoi, Vietnam*

ABSTRACT

The gear hobbing process is one of the most common and economical methods to machine the involute gear. The tooth profile deviations of the hobbed gears were caused by machine errors, hob errors and the deviation of the setting operations. In the paper, the influences of the run out of hob and the hob lead error on the tooth profile deviations of gears are analyzed through the position deviations of the generated point Pk on the cutting edge versus the surface of the imaginary rack. This report also proposes the method reducing the tooth profile deviations by adjusting the run out of hob suitable for the hob lead errors. The test result shows the effectiveness in decreasing the tooth profile deviations of hobbed gears.

KEYWORDS: Gear Hobbing, Run-Out & Tooth Profile Errors & Spur Gear

Received: Apr 27, 2019; **Accepted**: May 18, 2019; **Published**: Jun 14, 2019; **Paper Id.**: IJMPERDAUG20191

Original Article

INTRODUCTION

The gear hobbing process is the generating process repeating the transmission of the screw and gear pair, in which the screw acts as the cutting tool and the gear acts as the work piece. The tooth profile error of hobbed gears depends on the hob errors, machine errors, set up errors and the cutting conditions 12. However it is difficult to make hobs with high accuracy because of their complicated geometrical shapes, and a high precision gear cannot always be obtained with a precision hob because of the set up errors. In the hobbing process, the surface of the imaginary rack is generated by the rotating motion of the hob 34. The tooth profile deviation is caused by the movement of the generated point on the cutting tooth away from the surface of the imaginary rack. This paper analyzed the influences of the run out of hob and the hob lead error on the tooth profile errors of hobbed gears. The position deviations of the generated point Pk on the cutting edge versus the surface of the imaginary rack cause the tooth profile deviations of the hobbed gear. The tooth profile error of the hobbed gear can be reduced by adjusting the run out hob conforming to the hob lead errors. An experiment is set up and the experimental results are confirmed that the tooth profile deviations of the gears are reduced by adjusting the position run out of hob in the gear hobbing process.

The Movement of the Point of Cutting Edge Out to the Surface of the Imaginary Rack in the Generating Process

The gear hobbing process is the generating process repeating the transmission of the screw and gear pair, in which the screw acts as the cutting tool and the gear acts as the work piece, as figure 1.

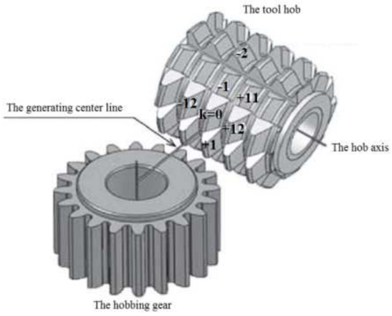


Figure 1: The Gear Hobbing Process

In the gear hobbing process, a cutting surface is generated by each cutting edge of the hob tool joining to the generated motion 5. The gear surface is formed by the innumerable cutting surfaces. A corresponding point with each point of the cutting edge is found in the imaginary rack surface. The position error of this generated point causes a tooth profile error. Figure 2 shows the movement of a point on a cutting tooth of the hob in the cutting process. The position of a point Pk in the edge k of hob is determined by the following equation:

$$X_{ki}=-R_k.\sin\theta_i.\sin\varphi-E_k.\cos\varphi$$

$$Y_{ki}=R_k.\cos\theta_i \quad (1)$$

$$Z_{ki}= R_k.\sin\theta_i.\cos\alpha-E_k.\sin\varphi$$

Where: Ek – The distance from the generating point Pk to the generating center

Rk – The radial of the point Pk

θi – The rotation angle Pki

φ – Inclination angle of the hob axis

α – Pressure angle

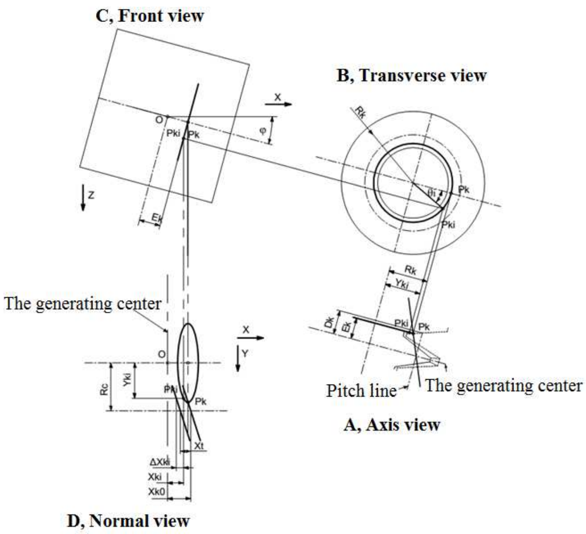


Figure 2: The Movement of a Point on a Cutting Tooth of the Gear Hob

The distance from the generating center to the generating point on the pitch line is determined by following equations:

$$X_{k0} = P.\frac{J}{N} + \frac{S_h}{2} \quad (2)$$

In where: j – The number of the cutting edge

N – The number of hob gash

Sh – The thickness of generated rack tool

P – The pitch of generated rack tool.

When the hob rotates from a point Pk to a point Pki with the rotational angle θi, the generated rack moves a distance Xt on the pitch line, determined by equation (3).

$$X_t = P.\frac{\theta_i}{2\pi} \quad (3)$$

On the view (D) in figure 2, the distance ΔXki between the point Pki on the cutting surface after rotating an angle θi and the corresponding cutting teeth on the generated rack surface measured in the X direction, which is determined by an equation (4). In the gear hobbing process, the deviations of the distance ΔXki cause the tooth profile of the machined gears.

$$\Delta X_{ki} = -X_{k0} + X_t + (R_c - Y_{ki}).\tan\alpha + X_{ki} = -P.\frac{k}{N} - \frac{S_h}{2} + P.\frac{\theta_i}{2\pi} + R_c.\tan\alpha - Rk.\sin\theta i.\sin\varphi - Rk.\cos\theta i.\tan\alpha + Ek.\cos\varphi \quad (4)$$

The deviations of the distance ΔXki cause the tooth profile of the hobbed gears. There are many factors causing the deviations of the distance ΔXki such as machine errors, hob errors and the deviation of the setting operations. However, in this research, the effects of the hob run out and the hob lead errors on the deviations of the distance ΔXki are studied and analyzed.

Influence of the Run out Hob on the Radial of the Point Pk

The tool hob is set on the hobbing machine after checking the accuracy of the spindle, hob holder shaft and hob. Then, the total run outs of hob e1, e2 are determined by two indicators at the both sides of hob tool as shown in the figure 3.

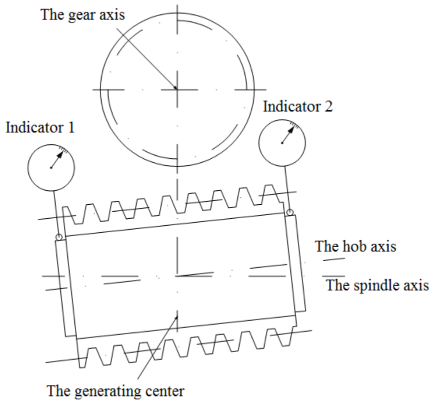


Figure 3: Measuring the Hob Run out Before the Cutting Process

These run outs of the hob cause the cutting edge to be moved away from the generated surface according to the two directions Y and Z as shown in Fig. 4. The hob run out at the point Pk is defined:

$$\Delta k = \sqrt{\Delta Y^2 + \Delta Z^2} \tag{5}$$

Where: ΔZ and ΔY is the eccentricity of the rotational axis at the point Pk following the Z and Z direction determined by the following formula:

$$\begin{cases} \Delta Y = e_1.\sin\varepsilon_1 + (e_2.\sin\varepsilon_2 - e_1.\sin\varepsilon_1)\frac{l_k}{l} \\ \Delta Z = e_1.\cos\varepsilon_1 + (e_2.\cos\varepsilon_2 - e_1.\cos\varepsilon_1)\frac{l_k}{l} \end{cases} \tag{6}$$

In where: e1, e2 – the run outs of hob, in the gear hobbing process e1<e2.

ε_1, ε_2 – The angle of the eccentricity vectors (e1, e2) and the generating center line

lk – The distance from the cutting edge k to the hob side with the run out e1.

lo – The length of the hob.

From there, the deviation radial of the point Pk is determined by the following equation.

$$\Delta R_k = \Delta_k.\cos(\theta_k - \varepsilon_k) = \Delta_k.\cos\left(k.\frac{2\pi}{N} - \varepsilon_k\right) \tag{7}$$

where: k – The number of the cutting teeth from the generating center.

ΔR_k– The deviation radial of the point Pk.

Δ_k – The run out of the hob at the point Pk (with e1< Δ_k<e2).

ε_k – The angle of the eccentricity vectors ek and the generating center line.

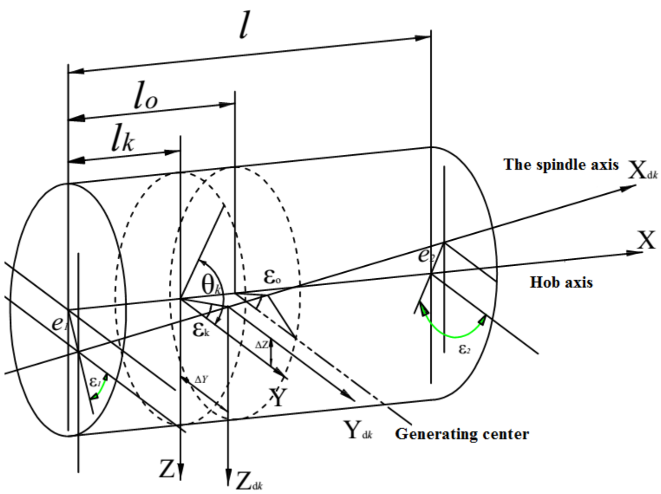


Figure 4: Effect of the Hob Run Out in the Hobbing Process

Influence of the Hob Lead Deviation on the Axial Distance from the Generating Point Pk to the Generating Center

In the gear hobbing process, the tooth profile deviations were mainly caused by geometrical error of hob. In there, the hob lead errors effect on the tooth profile errors and cause the sinusoidal errors of the tooth profile [6] [7] [8]. The hob lead errors cause the deviation of the axial distance from the generating point Pk to the generating center (Ek) in the equation (4). The hob lead errors are caused in the manufacturing hob and measured in the automation gear measuring

machine, shown in figure 6a. The deviation ΔE_k is determined by the equation (8).

$$\Delta E_k = A.\cos(k.\frac{2\pi}{N} - \Psi) \tag{8}$$

where: A – The maximum hob lead error in the machining area (μm)

k – The number of cutting tooth from the generating center line

N – The number of gashes

Ψ- The angle of the generating center line and the position of cutting tooth having the maximum hob lead error.

The Method for Reducing the Tooth Profile Errors

The accuracy of hobbed gears depend on the hob errors, machine errors, set up errors and the cutting conditions. However, the hob lead errors and the hob run out causes the position deviation of the generated point Pk and these deviations are sinusoidal. Suppose that the hobbing process only exists for two causes of errors: the hob lead error and the hob run out. The equation (4) can be rewritten:

$$\Delta X_{ki} = -P.\frac{k}{N} - \frac{S_h}{2} + R_c.\tan\alpha - (Rk + \Delta R_k).\tan\alpha + (Ek + \Delta E_k).\cos\varphi \tag{9}$$

The tooth profile deviations can be decreased by reducing the position deviations of the generated point Pk. These deviations caused by the hob lead errors and the run out hob can be determined:

$$F\Delta X_{ki} = -\Delta R_k \tan\alpha + \Delta E_k.\cos\varphi = A.\cos\varphi.\cos\left(k.\frac{2\pi}{N} - \Psi\right) - \Delta_k.\tan\alpha.\cos\left(k.\frac{2\pi}{N} - \varepsilon_k\right) \tag{10}$$

The tooth profile deviation of the hobbed gear gets the smallest value, the position deviations of the generated point gets the smallest value. Thus, the tooth profile error can be reduced by adjusting the hob run out according to the hob lead error as the equation (11).

$$\begin{cases} \Delta_k = \frac{A.\cos\varphi}{\tan\alpha} \\ \varepsilon_k = \Psi \end{cases} \tag{11}$$

EXPERIMENT

The cutting process uses the hobbing center of Mitsubishi and the tool hob made by Dragon company. The gear is made by the alloy steel SCM 420, have module 1.75 mm and 21 teeth, as figure 5. The table 1 shows the fundamental parameters of the tool hob. The experiment uses the manufacturing of the Futu1 company in Vietnam, as the table 2.

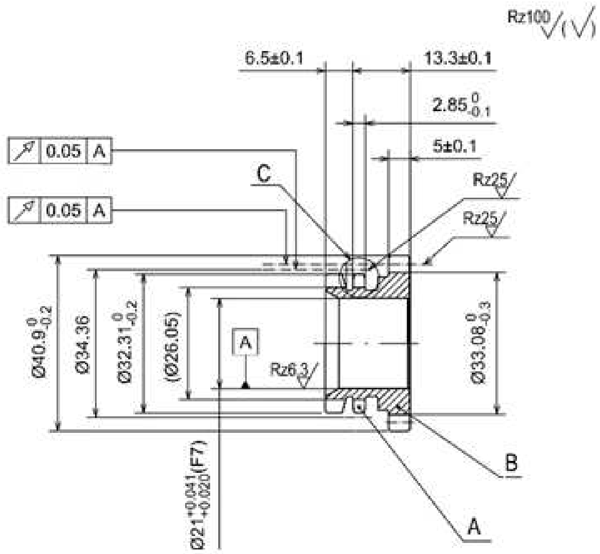


Figure 5: The Hobbing Gear

Table 1: The Technical Parameters of the Hob Tool

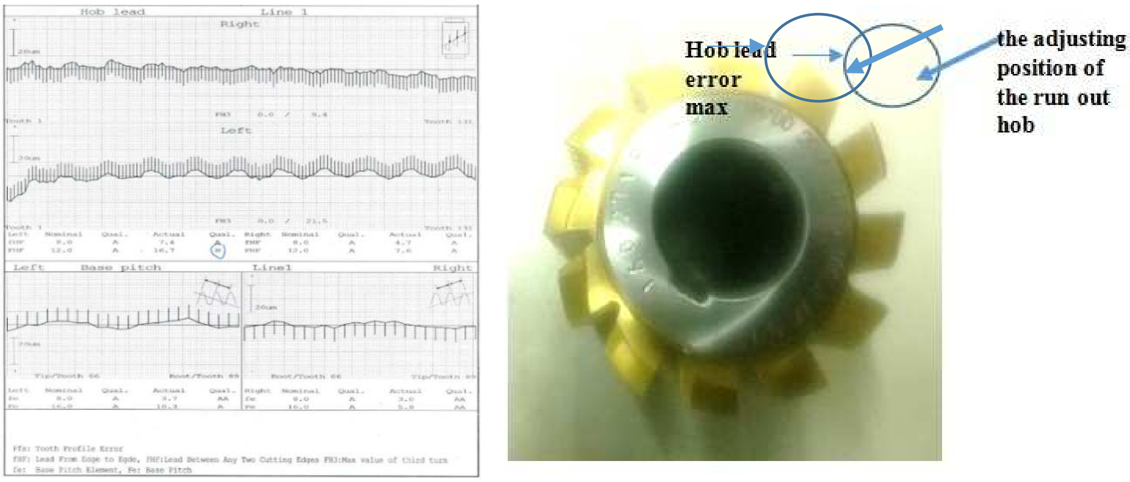
Company	Accuracy	Module (mm)	Out Diameter (mm)	Twist Angle	Number Gash	Material	Coated
DTR	DIN-AA	1.75	60	$1^{0}43’$	12	SKH-55	TIN

Table 2: The Parameters of the Hobbing Process in FUTU1

Spindle speed (rev/min)	300
Depth of cut (mm)	4.375
Feed rate (mm/rev)	1,27
Method	Up milling

The hob lead error is measured in the gear measuring center of OSAKA SEIKI KIKAI and shown in the figure 6a. In the experiment, the generating center is the cutting tooth having the maximum hob lead error ($\Psi = 0$). And the equation (8) can be shown as: $\Delta E_k = 6.\cos(k.\frac{2\pi}{N})$. Thus, in order to reduce the tooth profile deviations of the machined gear in the hobbing process, the position run out of hob have to set up as the figure 6b and the run out hob is smaller than 16.48 μm (following the equation 11 with A=6 μm, ϕ=1043’ and α=200).

The tooth profile deviations of the hobbed gear also is measured in the gear measuring center of OSAKA SEIKI KIKAI and shown in the figure 9-12. The figures 9a-12a show the tooth profile deviations of the machined gear in the hobbing process when the run out of hob was not adjusted by the equation (11) with the different run out values. The results show that when the position run out of hob is not set up as the figure 6b the tooth profile deviations of the machined gear in the hobbing process have the sinusoidal shape. When the hob run out increases from 5 μm to 22 μm, the maximum tooth profile deviations of the machined gears also increase from 10.3 μm to 24.4 μm. The figures 9b – 12b show the tooth profile errors of the hobbed gear, when the position run out of hob is set up as the figure 6b with the different run out values. The results show that when the run out of hob increases from 6 μm to 21 μm, the maximum tooth profile deviations of the machined gear in the hobbing process also increases from 7.3 μm to 21.8 μm. Thus, the experimental results are confirmed that the tooth profile errors of the hobbed gears are reduced by adjusting the position run out of hob as figure 6b.



a b

Figure 6: The Hob Lead Error Measured by the Gear Measuring Center (a) The Position having the Greatest Hob Lead Error and the Adjusting Position of the Run Out Hob (b)

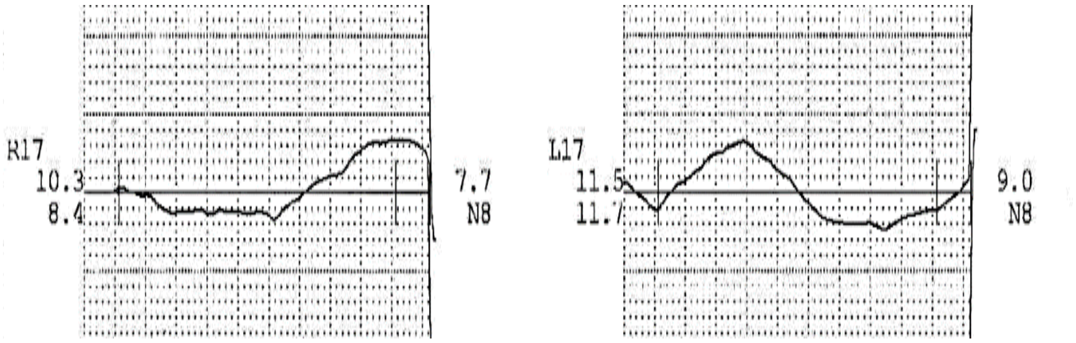


Figure 7a: The Tooth Profile Errors of Hobbed Gear when not Adjusting the Run Out of Hob with e2=5µm & e1=6µm

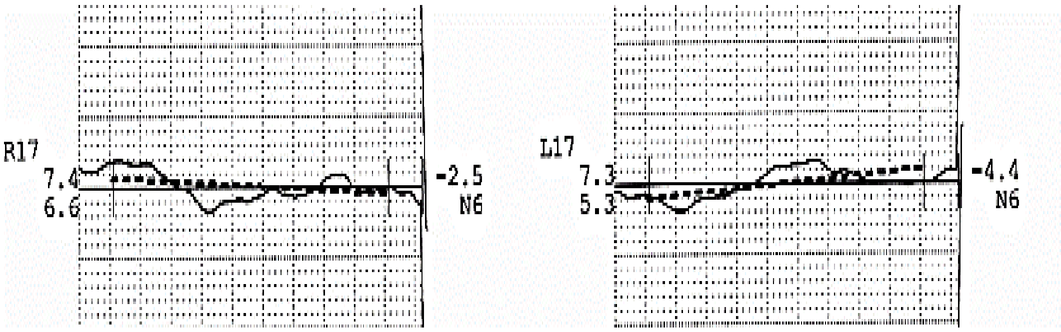


Figure 7b: The Tooth Profile Errors of Hobbed Gear when Adjusting the run out of hob with e2=6 µm & e1=6 µm

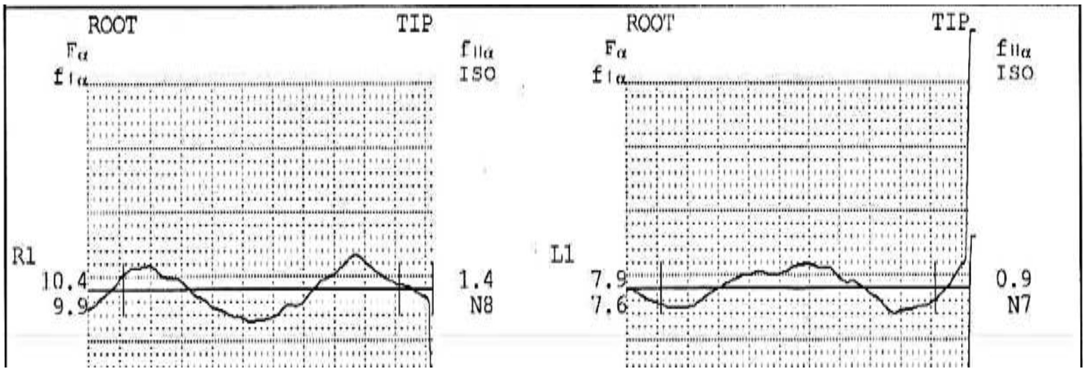


Figure 8a: The Tooth Profile Errors of Hobbed Gear when not Adjusting the Run Out of Hob with e2=10μm & e1=9μm

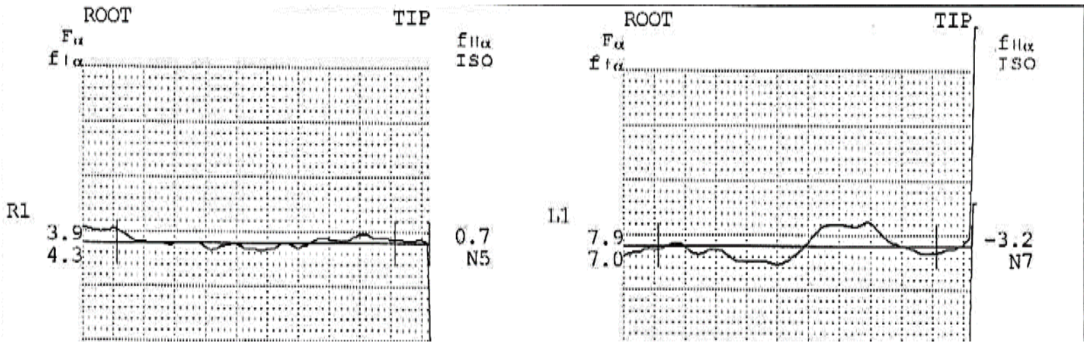


Figure 8b: The Tooth Profile Errors of Hobbed Gear when Adjusting the Run Out of Hob with e2=11 μm & e1=9 μm

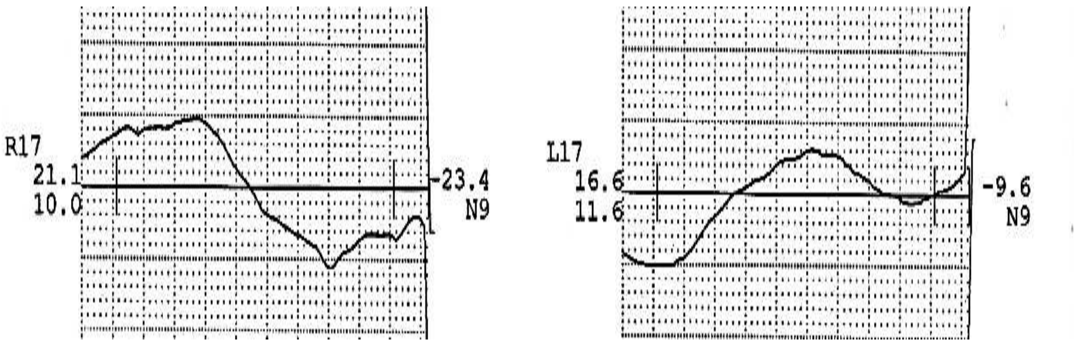


Figure 9a: The Tooth Profile Errors of Hobbed Gear when not Adjusting the Run Out of Hob with e2=16μm & e1=15μm

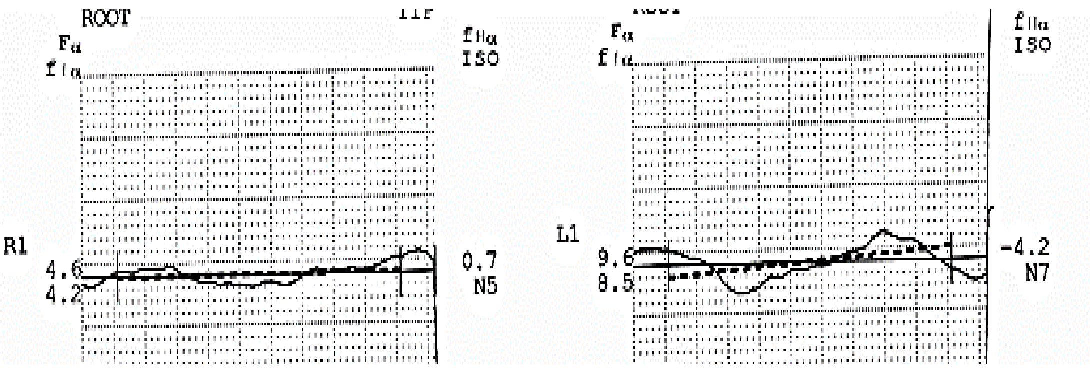


Figure 9b: The Tooth Profile Errors of Hobbed Gear when Adjusting the Run Out of Hob with e2=17 μm & e1=15 μm

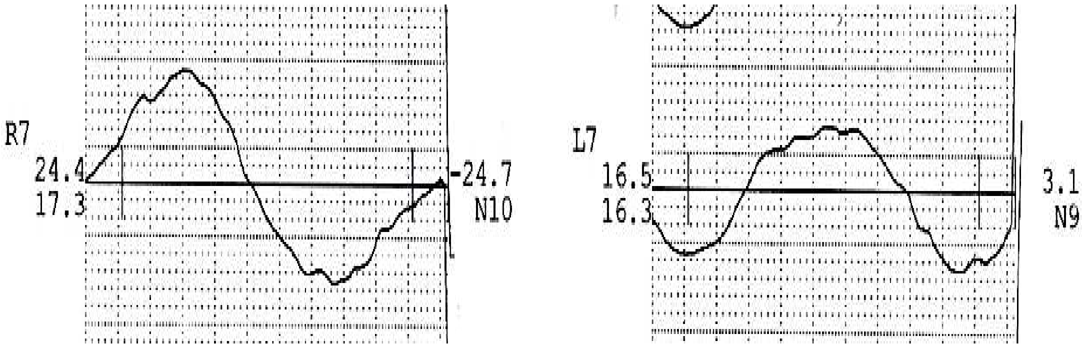


Figure 10a: The Tooth Profile Errors of Hobbed Gear when not Adjusting the Run out of Hob with e2=21µm & e1=19µm

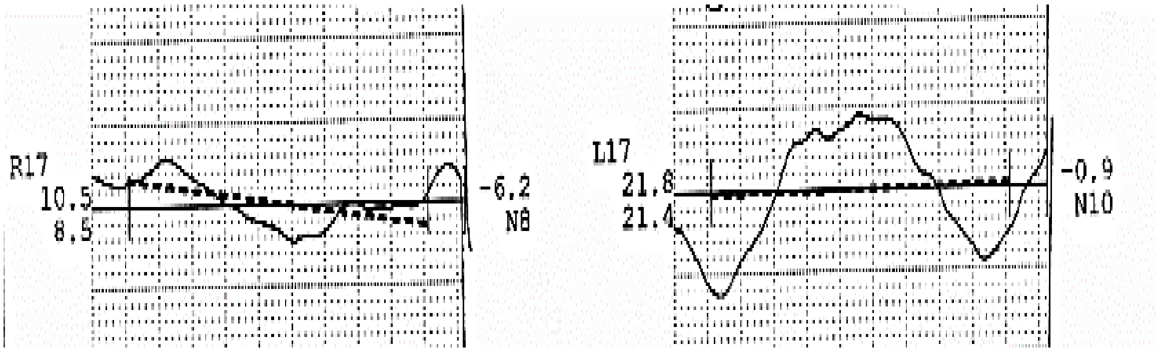


Figure 10b: The Tooth Profile Errors of Hobbed Gear when Adjusting the Run Out of Hob with e2=22 µm và e1=20 µm

CONCLUSIONS

A method for reducing the tooth profile deviations of the hobbed gear was proposed. The deviations of the distance between the generating point of cutting tooth of the tool hob and the surface of the imaginary rack cause the tooth profile deviations of the machined gear. By adjusting the run out hob conforming to the hob lead errors, the tooth profile error of the hobbed gear can be reduced. Thus, when the tooth profile error of the hobbed gear is mainly caused by the manufacturing and setting errors of the hob, the reducing the tooth profile errors is possible by adjusting the hob run out.

ACKNOWLEDGEMENTS

The work described in this paper was supported by Thai Nguyen university of Technology (http://www.tnut.edu.vn/) and FUTU1 company (http://www.futu1.com.vn)

REFERENCES

1. *Yoji Umezaki, Yasutsune Ariura, Taku Ueno, Kazahide Nagao, Tooth surface configurations caused by the errors in hobs and hobbing machines, JSME international journal, Japan, 1999, vol 32, No. 4, 654-662.*
2. *Mitsubishi CNC hobbing machine GE15A manual, Mitsubishi heavy industries Ltd, Tokyo Japan, 2015.*
3. *L.I.Xementsenko, V.M. Matyusin, G.N. Xakharov, the cutting tool design, 1973.*
4. *Kosuchon Satayotin, Yasuaki Hiroo, Mechanism of Spur Gear Hobbing, Pathumwan Academic Journal, 2014, Vol. 4, No. 11, 11 - 22.*
5. *Minh Tuan Ngo, Vinh Sinh Hoang, Modelling and determining the tooth profile total deviation of the hobbed gears in the CATIA environment, The 7th AUN/SEED-Net Regional Conference on Mechanical and Manufacturing Engineering, 2014.*

6. *Karma, V., & Borade, H. (2013). Fault diagnosis of single stage spur gearbox using narrow band demodulation technique: Effect of spalling. International Journal of Research in Engineering & Technology, 1(3), 11-16.*
7. *Brian W.cluff, Effects of hob quality and resharpening errors on generating accuracy, Gear technology, october 1987*
8. *Keith Liston, Hob basics Part I, Gear technology, October 1993.*
9. *Keith Liston, Hob basics Part II, Gear technology, December 1993.*